The SuperKEKB Project

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Abstract. SuperKEKB is a challenging project to explore new luminosity frontiers beyond 10^{35} $cm^{-2}s^{-1}$ by upgrading the KEKB collider, the asymmetric-energy electron-positron collider currently providing the highest luminosity (1.58×10^{34} $cm^{-2}s^{-1}$) on the planet. The design luminosity of SuperKEKB is 4×10^{35} $cm^{-2}s^{-1}$, where the beam currents need to be increased up to 4.1 A and 9.4 A for the high energy ring (8 GeV) and the low energy ring (3.5 GeV), respectively. In this report, the overall design of SuperKEKB is introduced and followed by RF and vacuum technological issues related to the high current beam.

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OVERVIEW: FROM KEKB TOWARD SUPERKEKB

KEKB [1] is a double-ring collider of electron and positron beams with asymmetric energies of 8 and 3.5 GeV, respectively. The KEKB collider, constructed in a tunnel with the circumference of about 3000 m at the Tsukuba campus of KEK, has been a cutting-edge machine exploring the luminosity frontier of the age of B-factories, dedicated to the purpose of producing a vast number of *B* meson pairs in order to investigate *B* meson physics, especially *CP* violation in the neutral *B* meson system. So far (as of Dec. 26, 2005), KEKB has delivered a total integrated luminosity of 528 fb^{-1}, whereas it has also achieved a peak luminosity of 1.627×10^{34} $cm^{2}s^{-1}$ with electron and positron beams of 1.35 and 1.72 A, respectively, and an integrated luminosity of 1206.6 pb^{-1} in 24 hours owing to the stable machine operation. Aiming at the next milestone for KEKB to deliver a total integrated luminosity of 1 ab^{-1}, the machine performance will be boosted by introducing a new maneuver to KEKB's beam-beam collision scheme with a finite crossing angle, that is, a head-on collision of crabbed bunches. Superconducting crab (deflecting) cavities under intensive R&D are going to be installed in early 2006.

SuperKEKB [2], a major upgrade of KEKB after the next milestone achieved, is a challenging project, which has been proposed to explore the luminosity frontier beyond 10^{35} $cm^{-2}s^{-1}$ searching for new physics beyond the Standard Model in parallel with the coming energy frontier machine LHC under construction at CERN. A schematic layout of SuperKEKB is shown in Fig. 1. The target luminosity is 4×10^{35} $cm^{-2}s^{-1}$, where the crabbing maneuver is assumed as de facto standard for the beam-beam collision scheme with a finite crossing angle. The project baseline is drawn along the construction by re-using most of the components of KEKB, especially the ring magnets (outside of the interaction region) and the RF power stations and sources (klystrons). However, there are also many components that need to be modified or newly developed. Toward the luminosity target of 4 x 10^{35} $cm^{-2}s^{-1}$, the beam currents need to be increased to 9.4 and 4.1 A for the 3.5-GeV low energy ring (LER) and 8-GeV high energy ring (HER), respectively. A higher beam current implies a large power loss to synchrotron radiation (SR) and higher order modes (HOM). This makes the design of the RF system and the vacuum system quite challenging.

We plan to use two types of RF cavities for SuperKEKB as well as for KEKB: one is normal conducting and the other superconducting. The normal conducting cavity, named ARES standing for Accelerator Resonantly coupled with Energy Storage, is a three-cavity system where an accelerating cavity is coupled with a large energy storage cavity via a coupling cavity between. The energy storage cavity functions as an electromagnetic flywheel to stabilize the accelerating mode. In the case of KEKB, the reactive effect of the beam loading on the accelerating mode can be reduced by one order of magnitude by increasing the stored energy ratio U_s/U_a to 9, where U_s is the electromagnetic stored energy in the storage cavity and U_a in the accelerating cavity. The superconducting cavity for KEKB is an axially symmetric single-cell cavity equipped with ferrite HOM absorbers inside the large diameter beam pipes at both ends. So far, 20 ARES cavities have been stably operated for the KEKB LER up to the beam current of 2.0 A, and 12 ARES and 8 superconducting cavities for the KEKB HER up to 1.36 A. Judging from the operational performance so far, we will probably be able to manage with 16 ARES cavities of the KEKB version for the SuperKEKB HER at 4.1 A, together with 12 superconducting cavities equipped with upgraded HOM absorbers. On the other hand, the SuperKEKB LER will be operated at 9.4 A with 28 newly built ARES cavities, for which we need to increase the energy ratio U_s/U_a from 9 to 15 and upgrade the power capabilities of the HOM loads.

The design of the vacuum system has been being carried out based on the experience obtained so far through the KEKB operation. We have found that antechambers and solenoid coils are very effective in suppressing the electron cloud instability. An antechamber, which consists of a beam channel and an SR channel connected through a narrow slot, is being considered to suppress the generation of photoelectrons, while solenoid coils will be mounted on the beam chambers prior to installation to prevent the build-up of electron clouds. Pumps are equipped on the upper and lower sides of the SR channel. In parallel with the baseline R&D, novel concepts have been introduced to vacuum components and intensively studied in KEKB; for example, the comb-type RF shield with a low impedance and a high thermal strength is very promising and expected to be widely applied to bellows chambers and gate valves for use under high current beams.

As mentioned above, the electron cloud instability will be a serious issue for the positron ring. The exchange of electrons and positrons between the LER and HER, that is a charge-switch scenario to reduce the beam current and increase the beam energy for positrons, may ease this kind of instability. For this scenario, we plan to use C-band accelerating structures, which realize the approximately double the energy gain of the S-band structures, in order to accomplish the energy upgrade of the positron injector within the restricted length of the beam line.

A damping ring for the positron beam will reduce the emittance of the injected beam. The lower emittance of the injected beam provides two benefits: the aperture of the ring can be kept small, and the detector background can be reduced during injection. Especially, the damping ring gives us flexibility in the design of the interaction region, which is severely restricted by aperture issues.

SUMMARY

The KEKB collider has been a cutting-edge machine exploring the luminosity frontier of the age of B-factories. SuperKEKB will be a decisive edge to continue the exploration beyond 10^{35} $cm^{-2}s^{-1}$ and its technically feasible design has been done.

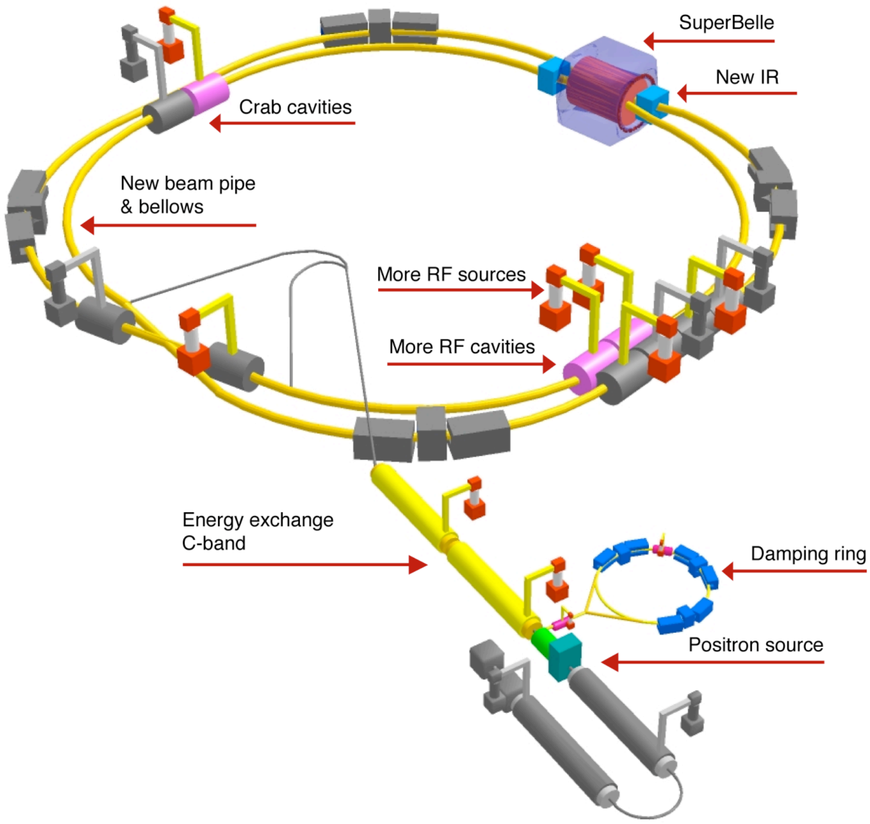

Figure 1. Schematic layout of SuperKEKB

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